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CHEMICAL FRACTIONATION OF SIDEROPHILE ELEMENTS IN IMPACTITES FROM AUSTRALIAN METEORITE CRATERS

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The abundance pattern of siderophile elements in terrestrial and lunar impact melt rocks has been used extensively to infer the nature of the impacting projectiles [1-3]. An implicit assumption made in previous investigations is that the siderophile abundance ratios of the projectiles are approximately preserved during mixing of the projectile constituents with the impact melt. As this mixing occurs during flow of strongly shocked material at high temperature, however, there are grounds for suspecting that the underlying assumption is not always valid. In particular, fractionation of the melted and partially vaporized material of the projectile might be expected because of differences in volatility, solubility in silicate melts, and other characteristics of the constituent elements. Impactites from craters with associated meteorites offer special opportunities to test the assumptions on which projectile identifications are based and to study chemical fractionation that has occurred during the impact process.

Impactites have been found at 4 of the 15 known terrestrial meteorite crater localities: (1) Meteor Crater, Arizona, (2) the Wabar craters, Saudi Arabia, (3) the Henbury Craters, Northern Territory, Australia, and (4) Wolfe Creek Crater, Western Australia. At all four localities with impactites, the associated meteorites are irons. In the course of geologic investigations of Australian impact structures, the Shoemakers discovered rare impactites at Wolfe Creek Crater [4] and carried out a survey of the fairly abundant Henbury impactites. They provided samples of these impactites for the present investigation together with a representative suite of ten specimens of the target rocks at Wolfe Creek Crater. Splits of four samples previously analysed for major elements by S. R. Taylor were used to study the target rocks at the Henbury Craters.

Wasson has identified the meteorites at both Wolfe Creek Crater and Henbury Craters as type IIIAB irons [5]. We analysed a Wolfe Creek iron collected by S. R. Taylor and a Henbury iron collected by C. S. Shoemaker. Although both meteorites were partly oxidized, we were able to isolate fresh metal portions for analysis. Our measurements are consistent with those of Wasson [6].

Instrumental neutron activation analysis was used to determine abundances for about 40 major, minor and trace elements that included the siderophiles Co and Ni. Abundances for Au and the heavy platinum group elements (Os, Ir, Pt) were determined by radiochemical separations following neutron activation. Siderophile abundances and relative fractionation data are presented in Table 1; abundances shown for impactites are net abundances after subtraction of the average background abundances of the target rocks. For our independent classification of the two meteorites we also measured Ga, As, and W. For Wolfe Creek, we found Ga=20 ppm, As=9.6 ppm and W=1.5 ppm; for Henbury, Ga=19 ppm, As=3 ppm, and W=1.6 ppm. The Wolfe Creek meteorite is an Ir-poor type IIIAB (B) and Henbury is an Ir-rich type IIIAB (A).

The meteoritic component of the impactites analysed ranges from about 0.06% to 10%. Except for Au at Henbury, the siderophile abundances are much greater in the impactites than in the average target rocks. Therefore, estimation of the meteoritic component of most siderophiles in the impactites is fairly insensitive to the estimate of the background abundance in the target rocks. Large fractionation relative to Ni is observed for most noble metals in the impactites. Platinum group elements tend to be depleted relative to Ni by about an order of magnitude in Wolfe Creek impactites, and gold is depleted by two orders of magnitude. The pattern of fractionation at Henbury is rather similar to that at Wolfe Creek, even though the abundances of Pt group elements are drastically different in the two meteorites. At Henbury, where the meteorite is Pt rich, Pt is less strongly fractionated in the impactite. Cobalt is consistently enriched relative to Ni in both Wolfe Creek and Henbury impactites.

The strong fractionation observed in the impactites from the Australian craters suggests that caution should be exercised in deducing the nature of impacting projectiles from siderophile element patterns in impact melt rocks or in suevites. The amount of fractionation may depend on many factors, including the velocity of the projectile, the temperature history of both the projectile and target material, oxidation state of the target material, the size of the crater, and the degree to which melt rocks or fallout units are representative of the ejected material. Siderophile abundance patterns resembling those of CI chondrites observed at some large craters such as East Clearwater Lake [7] suggest that, in favorable cases, the fractionation may be small. On the other hand, the high frequency with which impactors have been identified as differentiated objects [8,9] suggests to us that projectiles may have been misidentified in a number of cases because of unrecognized fractionation effects [10].

References:

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Table 1. Siderophile element abundances and relative fractionations in meteorites, impactites and target rocks at Wolfe Creek Crater, Western Australia, and at Henbury Craters, Northern Territory.

<u>Wolfe Creek Crater</u>

Sample		Ni (ppm)	Co (ppm)	Os (ppb)	Ir (ppb)	Pt (ppb)	Au (ppb)
meteorite		86000	5100	6.8	24	1760	1220
impactite-A		3360*	–	<0.08*	0.134*	–	–
impactite-B		6920*	580*	–	0.120*	15.1*	1.17*
background	(ave.)	2	1.5	<0.01	0.007	~0.13	0.12
	(high)	6.9	4.5	<0.01	0.011	~0.13	0.12
	(low)	0.9	0.4	–	0.005	–	–

Fractionation relative to Ni: $\frac{\text{Z (impactite/meteorite)}}{\text{Ni (impactite/meteorite)}}$

Sample	Ni	Co	Os	Ir	Pt	Au
impactite-A	1	–	<0.3	0.14	–	–
impactite-B	1	1.42	–	0.062	0.11	0.012

<u>Henbury Craters</u>

Sample		Ni (ppm)	Co (ppm)	Os (ppb)	Ir (ppb)	Pt (ppb)	Au (ppb)
meteorite		70600	5200	13200	15000	13500	400
impactite-A		161*	21.4*	5.25*	8.05*	20.6*	~0.03*
impactite-B		61*	12.8*	1.53*	2.64*	–	–
impactite-C		342*	38.9*	5.37*	13.9*	39.3*	~0.03*
background	(ave.)	20	8.9	<0.02	0.017	~0.1	0.64
	(high)	23	11.3	<0.02	0.027	~0.1	0.64
	(low)	15	7.2	–	0.013	–	–

Fractionation relative to Ni

Sample	Ni	Co	Os	Ir	Pt	Au
impactite-A	1	1.87	0.181	0.246	0.68	~0.04
impactite-B	1	2.83	0.133	0.202	–	–
impactite-C	1	1.52	0.084	0.190	0.60	~0.01

*Abundances shown for impactites are net abundances after subtraction of average backgrounds. For Os, Pt and Au, only one target rock background determination was performed for each impact site.